Characterizing the impact of altitude and finishing system on mean pulmonary arterial pressure and carcass characteristics in Angus cattle

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INTRODUCTION

High mountain disease (HMD) is a cardiopulmonary condition observed in cattle grazing at elevations greater than 1,500 m (Holt and Callan, 2007). The condition is characterized as the progression of pulmonary hypertension resulting from chronic exposure to environmental hypoxia at high altitude (Hecht et al., 1962). Cattle intolerant of these hypoxic conditions often undergo pulmonary vascular remodeling, pulmonary hypertension, cardiopulmonary insufficiencies, right heart failure, and death. HMD affects 3% to 5% of cattle at high altitude on average, but some ranchers have reported death losses as great as 25% (Holt and Callan, 2007; Neary et al., 2013a, 2013b; Bruns et al., 2015).

Once cattle start showing clinical signs of pulmonary hypertension, there are limited therapeutic remedies. The best indicator of HMD is mean pulmonary arterial pressure (mPAP) of cattle managed at high altitudes. mPAP is a veterinary procedure measured by threading a catheter containing a transducer through the jugular vein and right side of the heart in order to measure pressure in the pulmonary artery. This measurement indicates the animal's risk of developing HMD. Low-risk cattle have mPAP measurements less than or equal to 41 mm Hg, moderate-risk cattle will have a mPAP ranging from 42 to 48 mm Hg, and high-risk cattle have a mPAP of 49 mm Hg or greater (Holt and Callan, 2007).

Since the establishment of mPAP, symptoms reminiscent of HMD have been observed in a portion of feedlot cattle never exposed to high altitude. The phenomenon of pulmonary hypertension occurring in feedlot cattle is identified as feedlot heart disease (FHD). FHD can cause late-term feedlot death (Jensen et al., 1976; Neary et al., 2015a, 2015b). Common symptoms of HMD and FHD include, but are not limited to, jugular vein distension, edema, and lethargy. However, it is speculated that the conditions reflect distinct etiologies owing to the differing management practices that exist between ranches and feedlots. Krafsur et al., (2019) found that the physiology of FHD is characterized as significant pathophysiologic remodeling of the left ventricle and pulmonary venous circulation accompanying right heart and pulmonary arterial remodeling. Conversely, HMD has been characterized as pulmonary hypertension and right ventricular dysfunction (Rhodes, 2005). However, similarities and differences between HMD and FHD are still being investigated. Therefore, the objective of this study was to evaluate the impact of altitude and finishing ration on mPAP and carcass characteristics.

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MATERIALS AND METHODS

All animal care and experimental procedures were performed under protocols approved by the Colorado State University Institutional Animal Care and Use Committee.

Forty steers from the 2016 calf crop at the Colorado State University Beef Improvement Center (BIC) were randomly selected for the study based on their moderate mPAP (initial mPAP: 41.38 ± 0.46 mm Hg), age, and body weight at 10 mo of age. Steers were assigned to one of four treatment groups: high altitude stockered and grain-finished (HA_Grain), high altitude stockered and grass-finished (HA_Grass), high altitude stockered and moderate altitude grain-finished (Ext_Mod_Stocker), moderate altitude stockered and grain-finished (Norm_Mod_Stocker). Steers were allocated to finishing systems such that no statistically significant differences existed among group means for initial mPAP, age, and body weight at 10 mo of age (Table 1).

The stockering phase of the study commenced in April 2017. All groups that were stockered at high altitude (HA_Grain, HA_Grass, Ext_Mod_Stocker) were maintained at the Colorado State University BIC at an average elevation of 2,150 m. Groups that were stockered at moderate altitude (Norm_Mod_Stocker) were managed at the Eastern Colorado Research Center (ECRC) at an average elevation of 1,420 m. In August 2017, Ext_Mod_Stocker steers were relocated from BIC to ECRC for finishing. The finishing ration consisted of 13.35% crude protein and 1.47% net energy for gain. Finishing rations were administered from August 2017 until steers were harvested.

Pulmonary arterial pressure measurements and body weights were recorded every 6 to 8 wk for each finishing group throughout the study with the final measurements occurring within 2 wk of harvest. Once the average body weight for a finishing system reached target weight, approximately 544 kg, steers were harvested within 30 d. Steers assigned to the Ext_Mod_Stocker and Norm_Mod_Stocker finishing systems were harvested in December 2017. The HA_Grain steers were harvested in April 2017, and the HA_Grass steers were harvested in October 2018.

Upon completion of data collection, automated model selection was performed using the dredge command from the multimodel inference (MuMIN) package in R (R Core Team, 2013) with statistical significance being noted when $P < 0.05$. Effects considered in model selection predicting final mPAP were initial mPAP, age, and finishing system. Harvest age, initial mPAP, final mPAP, and finishing system were considered when selecting the most appropriate model for hot carcass weight (HCW), backfat, kidney, pelvic, and heart fat (KPH), ribeye area (REA), and yield grade (YG). The resulting models for mPAP, HCW, backfat, KPH, REA, and YG (Table 2) were fit, and estimated marginal means were used to compare means across finishing systems for mPAP and carcass characteristics.

RESULTS

Finishing system affected final mPAP such that HA_Grass steers had a preharvest mPAP that was greater than Ext_Mod_Stocker steers ($P = 0.006$)

Table 1. Initial mean mPAP, mean age, and mean yearling weight for each finishing system

Finishing system	Mean mPAP, mm Hg	Mean age, d	Mean weight at 10 mo of age, kg
HA_Grass, $n = 10$	41.40 ± 0.96^A	313.00 ± 5.62^A	253.56 ± 5.67^A
HA_Grain, $n = 10$	41.20 ± 0.96^A	314.00 ± 5.62^A	270.90 ± 5.67^A
Ext_Mod_Stocker, $n = 10$	41.90 ± 0.96^A	309.00 ± 5.62^A	258.55 ± 5.67^A
Norm_Mod_Stocker, $n = 10$	41.00 ± 0.96^A	304.00 ± 5.62^A	262.18 ± 5.67^A

[A]Within each column, different superscripts represent statistically significant differences of the means between finishing systems for the specified trait ($P < 0.05$).

Table 2. Final model selected for each trait of interest utilizing the multimodel inference function in R, where an X signifies inclusion in the model for the dependent variable in that row

Dependent variable	Initial mPAP, mm Hg	Age, d	Finishing system	Harvest age, d	Final mPAP, mm Hg
Final mPAP	X		X		
HCW			X		
Backfat			X	X	
KPH			X	X	
REA			X		
YG			X	X	X

Table 3. Final mean mPAP measurement, HCW, backfat, YG, REA, KPH, and number of days on study for each finishing system

Finishing system	Mean mPAP, mm Hg	Mean HCW, kg	Mean backfat, cm	Mean YG	Mean REA, cm^2	Mean KPH, %	Days on study
HA_Grass, *n* = 10	54.80 ± 1.54^{A}	322.50 ± 3.08^{A}	0.89 ± 0.23^{AB}	2.85 ± 0.24^{AB}	27.69 ± 0.41^{A}	1.26 ± 0.16^{A}	605
HA_Grain, *n* = 10	52.60 ± 1.80^{AB}	421.84 ± 3.58^{B}	1.42 ± 0.05^{A}	3.45 ± 0.04^{A}	29.97 ± 0.48^{B}	2.99 ± 0.03^{B}	407
Ext_Mod_Stocker, *n* = 10	46.60 ± 1.93^{B}	339.74 ± 3.83^{C}	0.76 ± 0.18^{B}	2.79 ± 0.18^{B}	32.77 ± 0.51^{C}	1.73 ± 0.12^{A}	307
Norm_Mod_Stocker, *n* = 10	47.60 ± 1.95^{B}	382.38 ± 3.86^{D}	0.91 ± 0.18^{B}	2.94 ± 0.18^{B}	31.24 ± 0.51^{BC}	1.72 ± 0.13^{A}	307

[ABCD]Within each column, different superscripts represent statistically significant differences of the means between finishing systems for the specified trait ($P < 0.05$).

as well as Norm_Mod_Stocker steers ($P = 0.024$). Steers in the HA_Grain finishing system exhibited no statistical difference when comparing final mPAP measures with those of the other three finishing systems. Furthermore, no statistical difference was observed between the final mPAP measurements of the Ext_Mod_Stocker and Norm_Mod_Stocker steers (Table 3).

HCW differed among treatment groups such that each finishing system yielded a different mean HCW ($P < 0.05$). Specifically, steers stockered and grass finished at high altitude (HA_Grass) exhibited the lowest mean HCW compared to all other finishing systems ($P < 0.001$) Steers of the Ext_Mod_Stocker treatment exhibited the second lowest HCW ($P < 0.001$). Conversely, HA_Grain steers had the greatest HCW of the finishing systems ($P < 0.001$), with the Norm_Mod_Stocker steers exhibiting the second largest HCW ($P < 0.001$) (Table 3).

Steers stockered and grain finished at high altitude (HA_Grain) exhibited an average carcass backfat thickness greater than Ext_Mod_Stocker ($P = 0.002$) and Norm_Mod_Stocker ($P = 0.03$) steers. Backfat did not differ between HA_Grass steers and all other finishing systems. Furthermore, Ext_Mod_Stocker and Norm_Mod_Stocker steers did not exhibit statistically significant differences in backfat (Table 3).

YGs differed such that HA_Grain steers exhibited a greater average YG than Ext_Mod_Stocker ($P = 0.001$) and Norm_Mod_Stocker ($P = 0.021$) steers, but not HA_Grass steers. Differences in YG were not significant when comparing HA_Grass, Ext_Mod_Stocker, and Norm_Mod_Stocker steers to one another (Table 3).

Steers in the HA_Grain finishing system had the greatest KPH ($P > 0.001$). However, no differences in KPH were observed between the HA_Grass, Ext_Mod_Stocker, and Norm_Mod_Stocker finishing systems (Table 3).

REA differed across finishing systems such that Ext_Mod_Stocker steers had an average REA that was larger than that of HA_Grain ($P < 0.001$) and HA_Grass ($P < 0.001$) steers, but not Norm_Mod_Stocker steers. The steers that were stockered and grass finished at high altitude (HA_Grass) had the smallest REA ($P < 0.001$). The steers stockered and grain finished at high altitude (HA_Grain) were statistically different from Ext_Mod_Stocker ($P < 0.001$) and HA_Grass ($P = 0.003$) steers (Table 3).

DISCUSSION

Steers that were stockered and grass finished at high altitude (HA_Grass) had a greater average final mPAP than Ext_Mod_Stocker and Norm_Mod_Stocker steers ($P < 0.05$). These steers were exposed to high altitude longer than any other finishing system. This length of time at high altitude is attributed to the steers of the HA_Grass finishing system taking longer to reach harvest weight. Conversely, Ext_Mod_Stocker and Norm_Mod_Stocker steers required the least amount of time to reach harvest weight. Steers in the Ext_Mod_Stocker finishing system were able to reach harvest weight and be harvested with the Norm_Mod_Stocker steers despite spending more time at high altitude. Furthermore, Ext_Mod_Stocker and Norm_Mod_Stocker steers exhibited no difference in their final mPAP measurements. The HA_Grain steers were harvested 4 mo after the Ext_Mod_Stocker and Norm_Mod_Stocker steers because they took longer time to reach harvest weight and to schedule a date to harvest them. However, the HA_Grain steers still reached harvest weight prior to the HA_Grass steers. These results indicate that length of exposure to high altitude may play a greater role in final mPAP measurement. However, all finishing systems exhibited an average final mPAP that would be indicative of a moderate-to-high risk of developing pulmonary hypertension. Although duration of exposure to high altitude may pose a greater threat, feeding a finishing ration intended for rapid weight gain also increases mPAP.

Carcass characteristics of the finishing systems differed such that HA_Grain steers had the greatest HCW, backfat thickness, and KPH. Conversely, Ext_Mod_Stocker and Norm_Mod_Stocker steers exhibited lower HCW, backfat thickness, KPH and YG, but greater REA. These results indicate that more of the carcass weight is in the form of muscle rather than fat for the Ext_Mod_Stocker and Norm_Mod_Stocker steers. The HA_Grass steers were intermediate to the HA_Grain steers and the Ext_Mod_Stocker and Norm_Mod_Stocker steers for all carcass characteristics, despite being exposed to high altitude for the longest duration of time. Although the HA_Grain steers had the heaviest carcasses, that group of steers did not get harvested right after reaching harvest criteria due to a delay in the harvest date that was set. This longer duration on study after reaching harvest weight could account for the increased fat deposition and heavier carcasses, resulting in differences when compared to the other finishing systems.

Although there are differences in carcass characteristics depending on finishing system, there are also differences in the amount of time each finishing group required to reach the harvest criteria, which was an average weight of approximately 544 kg. The Ext_Mod_Stocker and Norm_Mod_Stocker steers were harvested at 307 d on study. The HA_Grain steers were harvested at 407 d on study, and HA_Grass steers were harvested at 605 d on study. Steers finished at high altitude were heavier than those finished at moderate altitude, but took longer to reach harvest weight. Considering these results along with the carcass results, it is possible that a trade-off between days to harvest and carcass characteristics may exist for producers stockering and finishing cattle at high altitudes.

In summary, increased mPAP is observed at ranches and feedlots at both high and moderate altitudes, impacting cardiopulmonary health as well as carcass quality. Although it appears that altitude may play a greater role than finishing ration, as steers gain weight, their mPAP increases. Furthermore, when coupled with high altitude, finishing ration reduces REA while increasing backfat and KPH fat, resulting in greater YG. Therefore, it is important to continue characterizing mPAP and its impact on cattle in the stocker and finishing phases of beef production. Through determining a way to select and manage cattle to be more tolerant of altitude and finishing rations without succumbing to pulmonary hypertension, death loss on high altitude ranches and in feedlots at moderate altitudes may be reduced.

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